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Simulation of Zeta Converter based 3-Level NPC Inverter with PV System

D. Selvabharathi, R. Palanisamy, K.Selvakumar, V.Kalyanasundaram, D.Karthikeyan, Amal Nair, Kriti Karnavat, Annanya Sharma
Department of EEE, SRM Institute of Science and Technology, Chennai, India

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ABSTRACT

This paper proposes increasing the efficiency of the autonomous Photovoltaic (PV) system by utilizing zeta converter alongside neutral point clamped multilevel inverters (NPC-MLI) based on innovative PWM scheme. The PV system acts as an input source and the relevant control of zeta converter through maximum power point tracking (MPPT) offers the maximum available power from the PV array connected to DC-link. To obtain a high voltage gain we need to exhaust the dc-link voltage as much as possible and reduce stress on the switches. For this the NPC-MLI algorithm approaches PWM technique to perform capacitive charging in parallel and discharging in series to obtain maximum voltage gain. The proposed scheme is designed and verified via detailed simulations in the MATLAB/Simulink environment.

Corresponding Author:

R. Palanisamy,
Department of EEE,
SRM Institute of Science and Technology,
Chennai, India.
Email: krspalani@gmail.com

1. INTRODUCTION

In today's contemporary world, dire reduction in cost of power generation is required while keeping in mind the exhaustion of fossil fuels in near future thus paving way for other sources of energy [1]. The Photovoltaic system due to its enormous potential plays a vital role in meeting such demands. Solar energy is a very democratic form of energy [2], [3]. Because the sun shines everywhere, thereby the potential to utilize solar energy is available to everyone. Besides being a cheap, clean and quite source of energy it can be contrived into any size based on energy requirements and is visually unobtrusive [4]. Usually a transformer is used to transfer power from the system but it results in decreased efficiency. Thereforethe choice of topology should depend on parameters like Total Harmonic Distortion (THD), reduced common mode voltage, leakage current loss and voltage stress [5].

A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage from its input (supply) to its output (load). It plays the role of extracting the untapped energy and keeps the supply of current constant [6]. In a boost converter, the output voltage is always higher than the input voltage with low operating duty cycles [7]. The input current being continuous is very desirable for sources like PV or battery. Zeta converter is one such type of DC-DC converter which offers maximum power-point tracking of an SPV array. It has a continuous current output which is ripple free [8], [9].

Many industrial applications require high power as well as medium power for their operation. Using a high power source for all industrial loads may prove beneficial to some motors requiring high power, while it may damage the other loads [10]. The Multi level inverter is used for such industrial applications as alternative in high power and medium voltage situations. They can draw input current with low distortion,

have good harmonic rejection capacity, and can handle high voltages [11]. It has reduced dv/dt stresses on switching, increased efficiency of output due to greater reduction of common mode and can operate at both fundamental switching frequencies that are higher switching frequency and lower switching frequency. They possess low electromagnetic interference and the efficiency is considerably high.

2. PV ARRAY AND MPPT ALGORITHM

a) PV Array

PV cells are also known as solar cells. These cells absorb photons when they are exposed in sunlight. This leads to release of electrons which further leads to flow of current when it is connected to load. These cells are made of very pure semiconductor-grade polysilicon- a material processed from quartz and extensively throughout the electronics industry. Among widely used model of solar cells single-diode model and two-diode model are usually used in practical cases [12]. In single diode model there is a constant current source in parallel to diode and registers known as shunt registers and series registers. In single diode system identity factor is 1and in 2 diode system identity factor is considered as 2. PV panel is made up of large number of solar cells which may be connected either in series or parallel or combination of series and parallel, which totally depends on demand of load or device connected to source [13],[14].

b) MPPT Algorithm

A typical solar radiation converted into electrical energy by 35 to 45 percent from the solar panel. To improve the effectiveness of the solar panel maximum power point tracking is prepared. The extracting of maximum power decided when the solar irradiations and temperature will be constant. When the variations occur in solar irradiation and temperature, the improved MPPT method has to implement.

The zeta converter supplementary in the PV array side in order to augment the tracked power from the PV array. And by changing duty cycle of boost converter the requisite demand voltage can be achieved, that gives the source voltage matched with the load voltage. Based on this situation the PV voltage and current value deliberated.

The P&O algorithm chooses the maximum extracts of power based on the position movement. When the ratio of change in voltage to change in current is positive, then there is a small increment. If the ratio of change in voltage to change in current is less than zero, then the large increment will occur at the same position of tracking also change. By observance the solar irradiation and temperature as constant to take out the maximum power from the projected system.

3. NPC MLI

Out of the many multilevel arrangements the one which is widely acclaimed is the Neutral-Point-Clamped multilevel inverter. In here the multilevel NPC multilevel inverter is responsible to combine the small step of staircase output voltage from several levels of DC capacitor voltages. In an n-level NPC inverter arrangement there would be (k - 1) capacitors on the DC bus, 2(k - 1) switching devices per phase and 2(k - 2) clamping diodes per phase. The dc voltage is provided by the photovoltaic cell. e is split into 3 levels by using 2 DC capacitors, C1 and C2. Each capacitor attains Vdc/2 volts and each voltage stress will be limited to one capacitor level through clamping diodes. 3-Level Neutral Point Clamped MLI is shown in Figure 1.

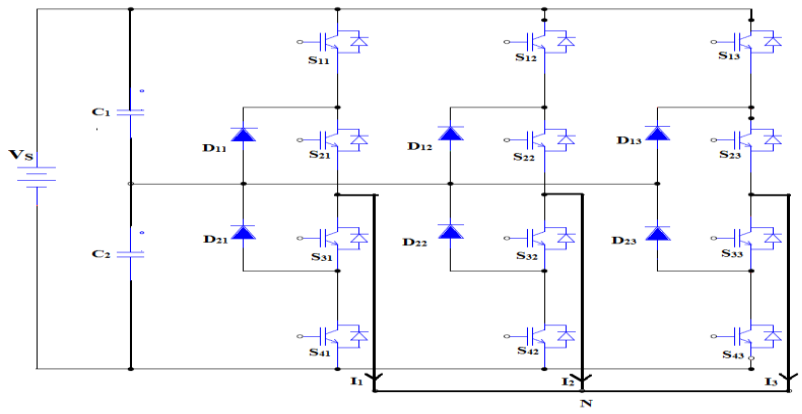

Figure 1. 3-Level Neutral Point Clamped MLI

In order to achieve higher AC voltage, additional switching devices will be used. The number of switching devices determines the level of inverter, higher the level more will be the voltage steps that will approach sinusoidal with minimum harmonic distortion. 3 level NPC inverter is used here to obtain efficient ac voltage output. In case of 3-level NPC inverter, as shown in Table 1, clamping diode clamps the DC bus voltage into three voltage level, +Vdc/2, 0 and -Vdc/2. Here are few modes of operation.

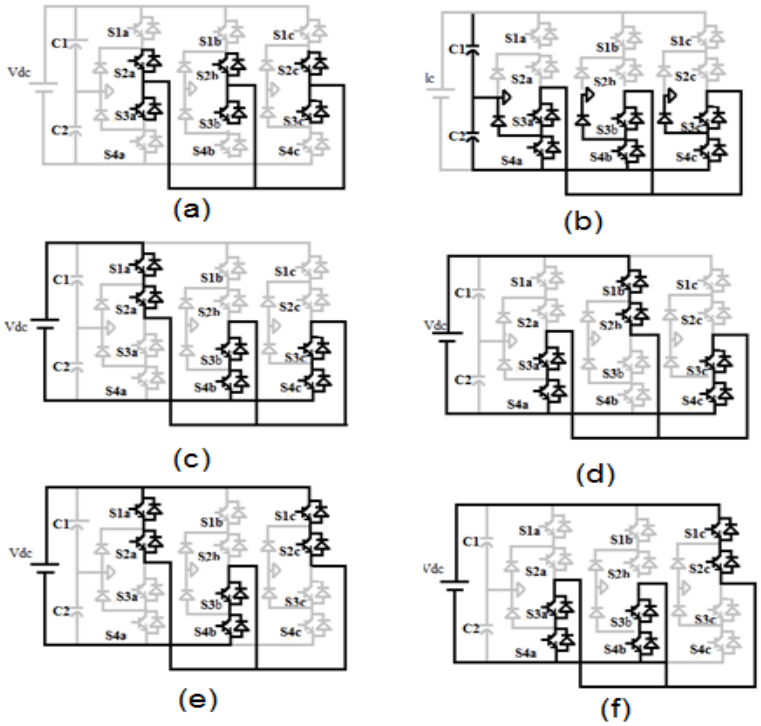

Figure 2. Modes of operation of 3-level NPC inverter

Table 1. Modes of operation of 3-level NPC inverter

Modes	Leg 1	Leg 2	Leg 3	Inverter Output
Mode 1	S2a, S3a	S2b, S3b	S2c, S3c	0
Mode 2	S3a, S4a	S3b, S4b	S3c, S4c	-3Vdc/2
Mode 3	S1a, S2a	S3b, S4b	S1c, S2c	Vdc/2

The modes of operation:
In mode 1, the switches S2a, S3a of leg 1; S2b, S3b of leg 2; S2c, S3c of leg 3 are switched ON and other switches are turned OFF. The bridge output voltage here is zero .
In mode 2, the switches S3a, S4a of leg 1; S3b, S4b of leg 2; S3c, S4c of leg 3 are in ON state and other switches are turned OFF. The bridge output voltage is -3Vdc/2 zero, which is shown in fig.2.
In mode 3, the switches S1a, S2a of leg 1; S3b, S4b of leg 2; S1c, S2c of leg 3 are in ON state and other switches are turned OFF. The bridge output voltage is +Vdc/2.
Similarly there can be different modes of operation based on the switching conditions. By shifting the phase by 120 degree and 240degree we can get a 3 phase stepped output. Similarly 27 switching modes can be obtained in 3-level NPC inverter system.

4. SINUSOIDAL PULSE WIDTH MODULATION (SPWM) TECHNIQUE

SPWM technique is one of the pulse width modulation (PWM) used to control power semiconductor switches, which generate the gating pulses by comparing the reference signals with carrier signals. Here the sinusoidal waveform acts as reference signal and triangular waveform act as carrier waveform, by comparing these two signals the required gating pulses generated. Each gating pulse width diverse proportionally to the amplitude of the sine wave assessed at the centre of the same pulse is shown in Figure 3.

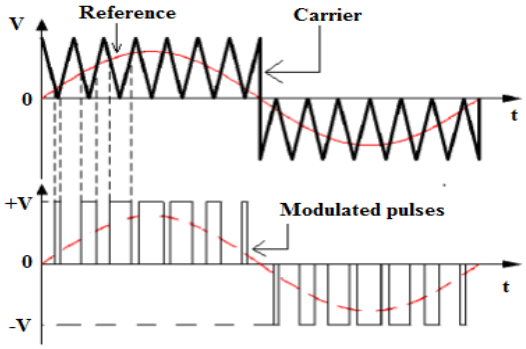

Figure 3. sinusoidal pulse width modulation technique

The output frequency (fo) of the NPC inverter can be ascertain by using the frequency of the reference signal (fr). The rms output voltage (Vo) can be inhibited by modulation index (M) and in turn modulation index is controlled by peak amplitude (Ar). The voltage can be embarrassed by the generate gating pulses from the controller. The number of pulses per half cycle depends on the carrier frequency.

$$M_a = \frac{V_c}{V_{car}}$$

Where, Vc – Peak magnitude of reference control signal, Vcar- Peak magnitude of carrier signal.

5. SIMULATION RESULTS AND DISCUSSION

The simulation of the proposed system was verified using MATLAB/simulink 11.b. The zeta converter based NPC inverter received the dc source voltage of 100V through PV system. The simulation parameters are inductors L1=L2=5 mH and capacitors C1=C2=270 micro Farad and the switching frequency of the inverter is 10 kHZ. The overall simulation diagram of the proposed system shown in Figure 4.

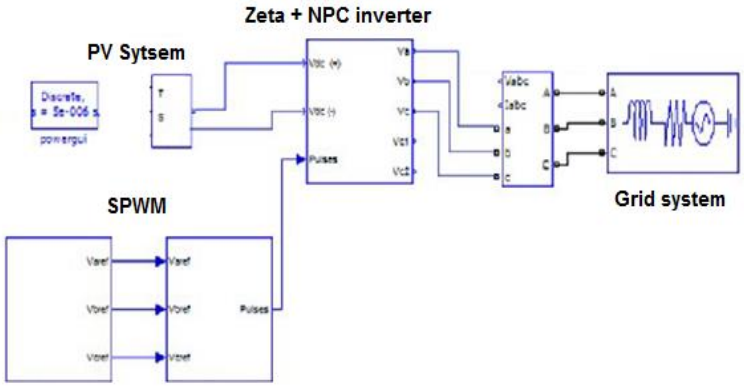

Figure 4. simulation model of proposed system

In Figure 5 shows the switching pulse generation using SPWM method, which is used to control the 3-level NPC inverter system. The output voltage waveform of the PV array is shown in Figure 6. And 3-Level NPC MLI Output Voltage is shown in Figure 7, which is 489.9 V. The THD of the proposed system is shown in Figure 8, in the Figure 8a & b shows the THD of output voltage and current respectively.

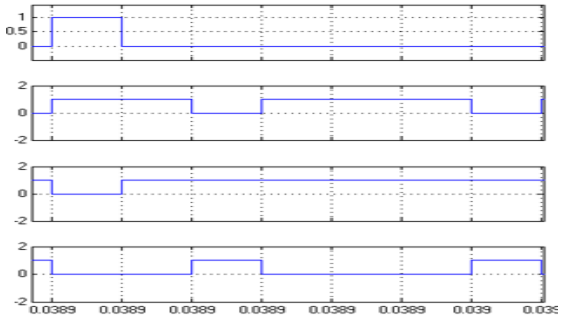

Figure 5. Switching pulses generation using SPWM method

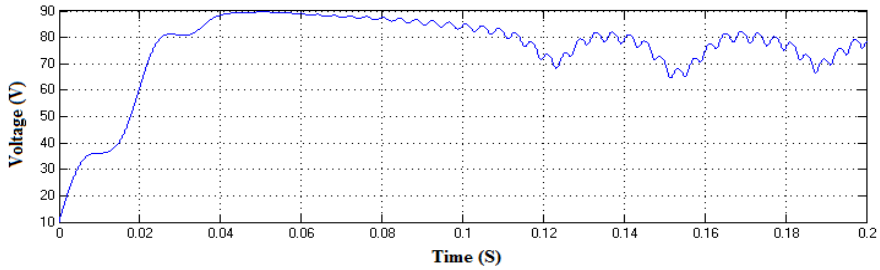

Figure 6. output voltage waveform of the PV array

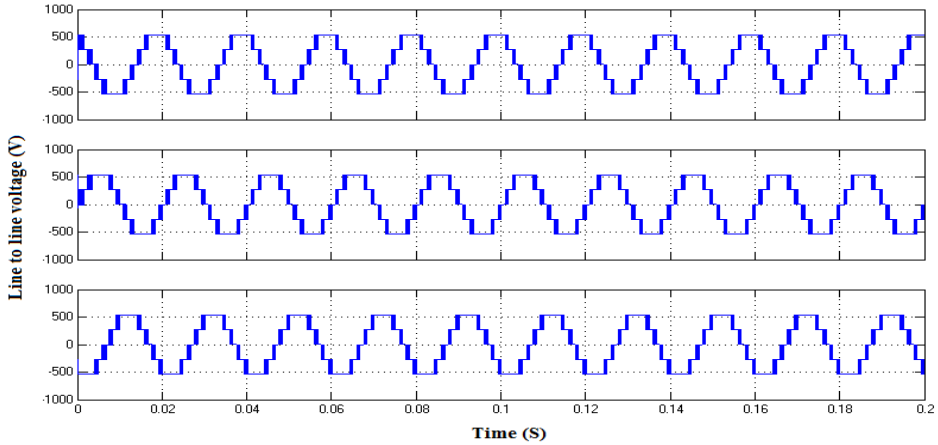

Figure 7. 3-Level NPC MLI Output Voltage

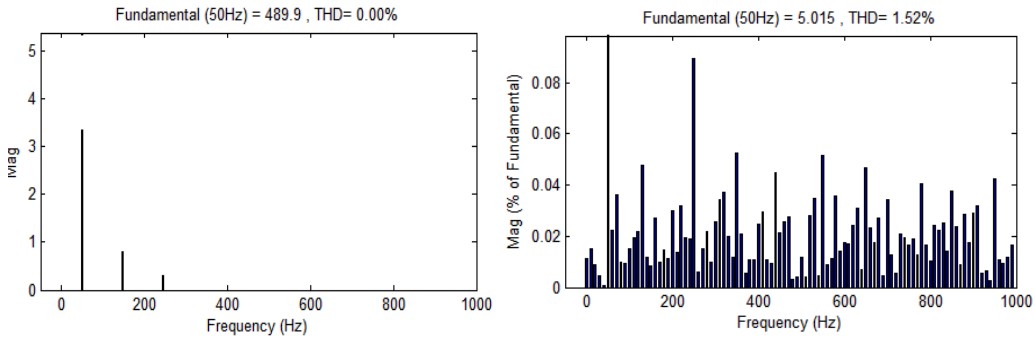

Figure 8. (a)THD for output voltage of NPC-MLI (b) THD for output current of NPC-MLI

6. CONCLUSION

This paper has presented a voltage controlled zeta converter based 3-Level NPC-MLI using SPWM with PV system. The output voltage of the proposed system is improved with minimized total harmonic distortion. The possible use of renewable solar energy and its conversion into a reliable three phase voltage supply has been discussed in the paper. PV system acts as an input source and the relevant control of zeta converter through maximum power point tracking (MPPT) offers the maximum available power from the PV array connected to DC-link. To obtain a high voltage gain we need to exhaust the dc-link voltage as much as possible and reduce stress on the switches. For this the NPC-MLI algorithm approaches PWM technique to perform capacitive charging in parallel and discharging in series to obtain maximum voltage gain.

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